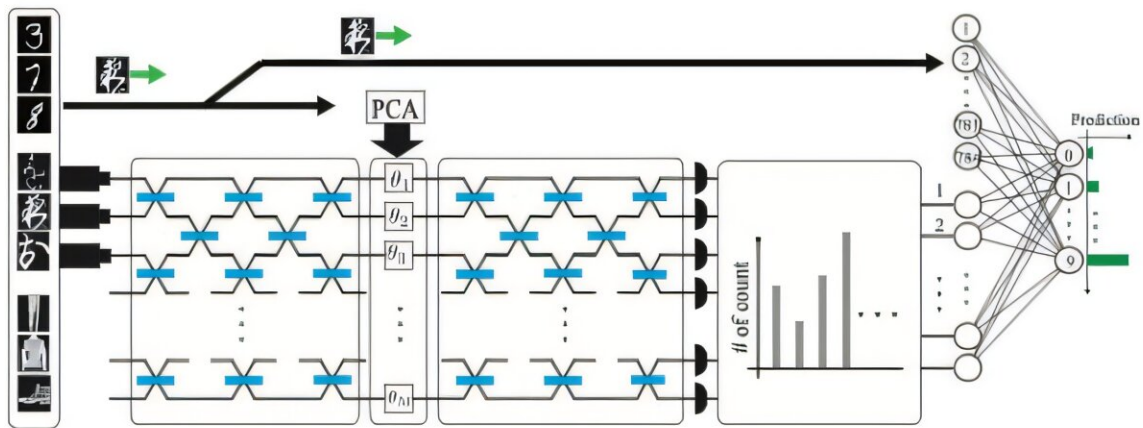


Boson sampling finds first practical applications in quantum AI

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In their simulated system, image data is first simplified using a process called principal component analysis (PCA), which reduces the amount of information while preserving key features. Credit: Sakurai et al., 2025

For over a decade, researchers have considered boson sampling—a quantum computing protocol involving light particles—as a key milestone toward demonstrating the advantages of quantum methods over classical computing. But while previous experiments showed that boson sampling is hard to simulate with classical computers, practical uses have remained out of reach.

Now, in *Optica Quantum*, researchers from the Okinawa Institute of Science and Technology (OIST) [present the first practical application of boson sampling for image recognition](#), a vital task across many fields, from forensic science to medical diagnostics. Their approach uses just three photons and a linear optical network, marking a significant step towards low energy quantum AI systems.

Harnessing quantum complexity

Bosons—particles like photons that follow Bose-Einstein statistics—exhibit complex interference effects when passed through certain optical circuits. In boson [sampling](#), researchers inject single photons into one such circuit, then measure the output probability distribution after they interfere.

To understand how such sampling works, think of marbles on a pegboard. When the marbles are dropped, if you sample the probability distribution of where the marbles land, it forms a bell curve. However, the results are completely different when running this same experiment using single photons.

They display wave-like properties, so can interfere with one another, and interact with their environment very differently from large objects. This means that they display very complex probability distributions, which are hard for classical computing methods to predict.

From quantum reservoir to image recognition

In this paper, the researchers developed a new quantum AI method for image recognition based on boson sampling. In their simulated experiment, they began by generating a complex photonic quantum state, onto which simplified image data was encoded.

The researchers used gray scale images from three different data sets as input. Since each pixel is in gray scale, the information is easy to represent numerically, and could be compressed using [principal component analysis](#) (PCA) to retain key features.

This simplified data was encoded into the [quantum system](#) by adjusting the properties of single photons. The photons then passed through a quantum reservoir—a complex optical network—where interference created rich, high-dimensional patterns.

Detectors recorded photon positions, and repeated sampling built a boson sampling probability distribution. This quantum output was combined with the original image data and processed by a simple linear classifier.

This hybrid approach preserved information and outperformed all comparably sized machine learning methods that the researchers tested, providing highly accurate image recognition across all data sets.

"Although the system may sound complex, it's actually much simpler to use than most quantum machine learning models," explained Dr. Akitada Sakurai, first author of this study, and member of the Quantum Information Science and Technology Unit.

"Only the final step—a straightforward linear classifier—needs to be trained. In contrast, traditional quantum machine learning models typically require optimization across multiple quantum layers."

Professor William J Munro, co-author and head of the Quantum Engineering and Design Unit, added, "What's particularly striking is that this method works across a variety of image datasets without any need to alter the quantum reservoir. That's quite different from most conventional approaches, which often must be tailored to each specific

type of data."

Unlocking new frontiers in image recognition

Whether it's analyzing handwriting from a [crime scene](#), or identifying tumors in MRI scans, [image recognition](#) plays a vital role in many real-world applications. The promising results of this study found that this quantum approach identified images with higher accuracy than similarly sized machine learning methods, opening new avenues in quantum AI.

"This system isn't universal—it can't solve every computational problem we give it," noted Professor Kae Nemoto, head of the Quantum Information Science and Technology Unit, Center Director of the OIST Center for Quantum Technologies, and co-author of this study.

"But it is a significant step forward in quantum machine learning, and we're excited to explore its potential with more complex images in the future."

More information: Akitada Sakurai et al, Quantum optical reservoir computing powered by boson sampling, *Optica Quantum* (2025). [DOI: 10.1364/OPTICAQ.541432](#)

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